PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04R 25/00	A1	(11) International Publication Number: WO 96/21333 (43) International Publication Date: 11 July 1996 (11.07.96)

(21) International Application Number: PCT/US95/16994

(22) International Filing Date: 29 December 1995 (29.12.95)

(30) Priority Data:
08/366,284 29 December 1994 (29.12.94) US

(71) Applicant: CENTRAL EAR RESEARCH INSTITUTE, INC. [US/US]; 3400 Northwest 56th Street, Oklahoma City, OK 73112-4466 (US).

(72) Inventor: DORMER, Kenneth, J.; 3430 Everett Drive, Edmond, OK 73013 (US).

(74) Agents: LaBRIE, Michael, J. et al.; Dougherty, Hessin, Beavers & Gilbert, Two Leadership Square, Suite 1400, 211 North Robinson, Oklahoma City, OK 73102 (US).

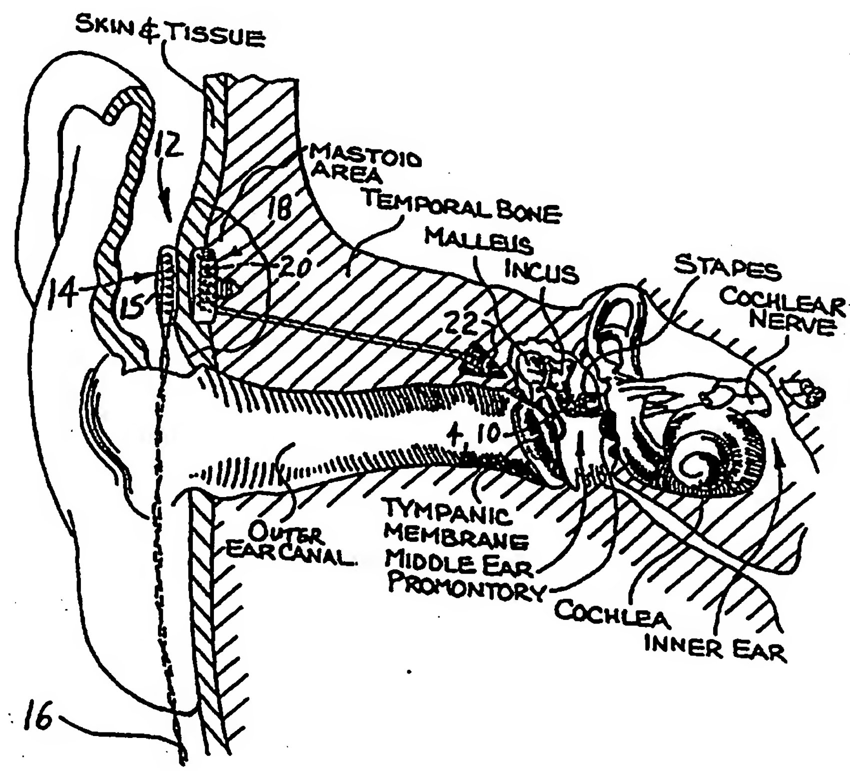
(81) Designated States: JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: IMPLANTABLE MAGNETOSTRICTIVE HEARING AID APPARATUS, DEVICE AND METHOD

(57) Abstract

The improved hearing aid apparaus (12) of the present invention includes : sound processing component (14) for eceiving sound and for converting the ound into an electromagnetic signal and magnetostriction device (4) for vibratıg within an auditory path of the user in esponse to the electromagnetic signal to timulate an inner ear to create the percep-.on of sound. The magnetostriction deice (4) of the present invention includes body (10) implantable in an implant auitory path of an implant recipient. The agnetostriction device (4) is composed f a biocompatible magnetostriction mateal so that the body (10) undergoes elastic eformation and restoration within the auitory path in response to a varying elecomagnetic field applied as a representaon of a sound to be perceived by the imant recipient. The method of the present vention comprises artificially generating und representing oscillations within an iditory path.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

IMPLANTABLE MAGNETOSTRICTIVE HEARING AID APPARATUS, DEVICE AND METHOD

Background of the Invention

This invention relates generally to hearing aids and methods and more particularly, but not by way of limitation, to an implantable magnetostrictive hearing aid device which undergoes elastic deformation and restoration in response to an electromagnetic field to create the perception of sound in an implant recipient. "Hearing aid" is used descriptively as referring to something for aiding a user to hear or in some manner sense or perceive sound. In this sense the present invention is a hearing aid, but preferred embodiments of the invention are technically referred to as implantable hearing devices (IHDs). Such a preferred embodiment is specifically a magnetostrictive IHD.

The perception of sound in a person normally occurs when sound waves strike the tympanic membrane causing the small bones of the ossicular chain in the middle-ear to vibrate. The middle-ear vibrations are conducted through the membranes of the oval and round windows, resulting in electrical impulses being transmitted from the cochlea through the auditory or cochlear nerve to the brain. However, some individuals are hearing impaired because this transmission chain does not function properly. For example, the transducers of the inner ear (hair cells) may be reduced in number resulting in sensorineural hearing loss.

Hearing aids are available to improve the perception of hearing in sensorineural-impaired individuals. One conventional hearing aid which is widely used is an "air-conduction" type apparatus. Air-conduction hearing aids merely amplify the incoming sound. However, some hearing-impaired persons derive little or no benefit from

an air-conduction hearing aid because of insufficient amplification, poor frequency response or acoustic feedback oscillation noise.

A cochlear implant hearing aid is referred to in U.S. Patent No. Re. 32,947 to Dormer et al., incorporated herein by reference.

Another kind of hearing aid is a "bone-conduction" type apparatus. A bone-conduction hearing aid converts sound waves into a mechanical vibration which vibrates the cochlear capsule, thus stimulating the cochlea and creating the perception of sound in a user. See U.S. Patent No. 4,612,915 to Hough et al. and U.S. Patent No. 4,774,933 to Hough et al., both of which are incorporated herein by reference.

Another kind of hearing aid, specifically of the IHD type, is shown in U.S. Patent No. 4,606,329 to Hough, which is incorporated by reference herein. This patent discloses converting sound into an electromagnetic signal and transmitting the electromagnetic signal transcutaneously. A circuit implanted subcutaneously in the temporal bone of the user outside of the middle-ear receives the electromagnetic signal and electromagnetically transmits a responsive signal into the middle-ear of the user. A magnet is implanted in the ossicular chain in the middle-ear. The magnet responds to the responsive signal and vibrates the ossicular chain in the middle-ear to stimulate the inner ear to create the perception of sound in the hearing impaired user. This patent discloses various forms of the aforementioned magnet, including some of the alternative variations for implanting this vibration generating component in the middle-ear of the hearing impaired person. See also U.S. Patent No. 5,015,225 to Hough et al., which is incorporated herein by reference.

Other IHD embodiments are described in U.S. Patent No. 4,776,322 to Hough et al., which is incorporated by reference herein. This patent discloses positioning the

entire hearing aid in the skull of the user. This invention is disclosed in two embodiments: one in which the sound processing means is located in but removable from the outer ear canal and one in which the hearing aid device is totally implanted within the skull of the user.

Despite the foregoing, there is the need for a hearing aid that has relatively lower energy requirements. This allows a battery to be used longer. It also allows for increased miniaturization, such as by permitting a smaller battery to be used for energizing the hearing aid. There is also the need for a hearing aid which provides more precise and greater vibration within the user's ear in response to a driving signal. Therefore, there is the more general need for an improved hearing aid apparatus, device and method.

Summary of the Invention

The present invention provides an improved implantable hearing aid apparatus, device and method which meet the needs described above.

The hearing aid device comprises a body adapted to be implanted in an implant auditory path of an implant recipient. The body is composed of a biocompatibly adapted magnetostrictive material so that the body undergoes elastic deformation and restoration within the implant auditory path in response to a varying electromagnetic field applied as a representation of a sound to be perceived by the implant recipient.

The hearing aid apparatus of the present invention comprises sound processing means for receiving sound and for converting the sound into an electromagnetic signal, and the apparatus further comprises magnetostrictive means for vibrating within an auditory path of the user in response to the electromagnetic signal to stimulate an inner ear of the user to create the perception of sound in the user.

This invention also provides a method of stimulating the inner ear to create the perception of sound in a human, comprising artificially generating sound representing oscillations within an auditory path of a human, including magnetostrictively driving a member of the group consisting of ossicles of a middle-ear of the human, a membrane of an oval window adjacent the middle-ear, a membrane of a round window adjacent the middle-ear and a related tympanic membrane, in response to a sound so that the driven member produces and transmits the oscillations into the inner ear, thereby stimulating the inner ear.

The present invention has a lower energy requirement to obtain a given displacement for generating movement in the implant auditory path. This can result in decreased battery drain and greater miniaturization of the implantable magnetostrictive apparatus. Furthermore, the amplitude of sound restoration can be greater to the implant recipient, improving hearing restoration for every level of mild-moderate-high sensorineural hearing impairment. Also, the magnetostrictive member has a precise axis of motion that can be positioned for more exact vibration of the ossicles, the membrane of the round window, the membrane of the oval window or the tympanic membrane.

It is therefore a general object of the present invention to provide an improved implantable hearing aid apparatus, device and method. Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the following disclosure when taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is a block diagram of the apparatus of the present invention.

FIG. 2 is an enlarged sectional view through an ear canal of a user with a first embodiment of an implantable magnetostrictive hearing aid apparatus of the present invention in position.

FIG. 3 is an enlarged sectional view through the ear canal of the user with a second embodiment of the implantable magnetostrictive hearing aid apparatus of the present invention in place.

FIG. 4 is an enlarged sectional view through the sound processing means utilized in the hearing aid apparatus illustrated in FIG. 3.

FIG. 5 is an enlarged sectional view through the ear canal of the user with a third embodiment of the implantable magnetostrictive hearing aid apparatus of the present invention in place.

FIG. 6 is an enlarged sectional view through the ear canal of the user with an embodiment of the implantable magnetostrictive hearing aid apparatus wherein a magnetostrictive body and a coil are located within the implant auditory path.

FIG. 7 is a composite view of various forms of the magnetostrictive device of the hearing aid apparatus shown in FIGS. 2-6.

FIGS. 8-18 are partial views of the ear canal illustrating various alternative attachments of the magnetostrictive device in the user.

Detailed Description of the Preferred Embodiments

Referring to the drawings, presently preferred embodiments of the invention and their operation are illustrated. Like reference numerals refer to like parts throughout the drawings and this description.

Referring to FIG. 1, the implantable magnetostrictive hearing aid apparatus of the present invention is shown by a block diagram. FIG. 1 shows an apparatus which includes sound processing means 2 for receiving sound waves, converting the sound waves into an

electromagnetic signal and transmitting the electromagnetic signal into an implant auditory path of a user where magnetostrictive means 4 is at least partially located. The magnetostrictive means 4 mechanically drives structure of the implant auditory path. By mechanically driving a structure in the implant auditory path, the perception of sound is created in the hearing impaired user or implant recipient. "Implant auditory path" as used herein means the auditory path defined from the tympanic membrane through a middle-ear and oval window to a related round window.

The magnetostrictive means 4 of the present invention can be used in combination with existing sound processing means 2. While only illustrative, the preferred embodiments which follow show different means for processing sound into an electromagnetic signal which effects elastic deformation and restoration of the implanted magnetostrictive means 4.

Referring to FIG. 2, which but for the nature of element 10 described hereinbelow is the same as a figure disclosed in U.S. Patent No. 4,606,329, which patent is incorporated herein by reference, a first embodiment of an implantable magnetostrictive hearing aid apparatus is illustrated and designated generally by the numeral 12. This embodiment of hearing aid apparatus 12 has a sound processing component 14 for converting sound into an analog electromagnetic signal. The sound processing component 14 can include an output transmitter 15 for transmitting a first electromagnetic signal transcutaneously. The output transmitter 15 is connected by wiring 16 to a microphone and associated circuitry enclosed in a case (not shown).

The transmitter 15 is placed supercutaneously on the skull of the user for transmitting the first electromagnetic signal transcutaneously to a signal receiving and transmitting means or component 18 which is implanted subcutaneously in the temporal bone outside of

the middle-ear of the user. Signal receiving and transmitting component 18 includes (1) a receiving means 20 for receiving the transcutaneous electromagnetic signal from the transmitter 15 and (2) a transmitting means 22 for transmitting a second, responsive electromagnetic signal subcutaneously into the implant auditory path of the user.

In FIG. 2, magnetostrictive means 4 includes a magnetostrictive body 10 implanted in the ossicular chain in the middle-ear. The malleus, incus and stapes together comprise a normal ossicular chain. The magnetostrictive means 4 can be connected within the ossicular chain (either to a bone thereof or in place of a bone or part thereof) as shown in FIG. 2, or it can be connected to tissue apart from the ossicular chain but within the implant auditory path. The magnetostrictive means 4 can be connected directly to a membrane of an oval window or round window or to a tympanic membrane as explained further hereinbelow.

Referring to FIG. 2, magnetostrictive body 10 receives, by being disposed within the field of the signal, the subcutaneous electromagnetic signal from the transmitting component 22 and vibrates the ossicular chain in response to this electromagnetic signal. This vibration stimulates the normal functioning of the inner ear to create the perception of sound in the hearing impaired user.

Referring to FIGS. 3 and 4, which but for the nature of element 10 are the same as figures shown in U.S. Patent No. 4,776,322, which patent is incorporated herein by reference, a second embodiment of an implantable magnetostrictive hearing aid apparatus is designated generally by the numeral 30. The sound processing means 2 of hearing aid apparatus 30 includes a microphone 34 for receiving sound waves, an electronic means 36 connected to microphone 34 for converting the sound waves into an electromagnetic signal, and an output transmitter

38 for transmitting the electromagnetic signal into the middle-ear. The output transmitter 38 is disposed in body portion 40 of the sound processing means 2 of the embodiment of FIGS. 3 and 4.

Hearing aid apparatus 30 also includes magnetostrictive means 4 shown as body 10 the same as illustrated in FIG. 2; however, the variations referred to herein are also applicable to the present embodiment. Just as in FIG. 2, the illustrated magnetostrictive means 4 receives the electromagnetic signal from the sound processing means 2 and vibrates the ossicular chain in response to the electromagnetic signal, which stimulates the inner ear to create the perception of sound in the hearing impaired user.

Hearing aid apparatus 30 shown in FIGS. 3 and 4 can be positioned in the ear canal of a user since external sound processing means has been eliminated.

Referring to FIG. 5, which but for the nature of element 10 is the same as a figure disclosed in the aforementioned U.S. Patent No. 4,776,322 already incorporated herein by reference, a third embodiment of an implantable magnetostrictive hearing aid apparatus is designated generally by the numeral 50. Hearing aid apparatus 50 includes a sound processing component 52 which can be positioned in or on the skull of a user. The sound processing component 52 includes a microphone 54 for receiving sound waves and an electronic means 56 connected to the microphone 54 for converting the received sound waves into an electromagnetic signal. The sound processing component 52 is enclosed within a subcutaneous housing 58.

Electrodes 60 connect the electronic means 56 to an output transmitter 62. The output transmitter 62, which is imbedded in the temporal bone in close proximity to the middle-ear, transmits the electromagnetic signal into the implant auditory path of the user.

Magnetostrictive means 4 is shown in FIG. 5 the same as in FIGS. 2 and 3 and the same explanation applies here.

Like hearing aid apparatus 30, hearing aid apparatus 50 can be positioned in the skull of a user.

The above three embodiments are illustrative only and the present invention is not limited merely to the apparatus shown. For example, in the above embodiments magnetostrictive means 4 is spaced from a coil such that magnetostrictive means 4 is located within the implant auditory path and the coil is located outside of the implant auditory path. However, as shown in FIG. 6, magnetostrictive means 4 and coil 66, which is connected to electrodes 60, can both be located within the implant auditory path. In a specific implementation, the coil 66 can be wound around the magnetostrictive body 10. More generally, the sound processing means 2 of the apparatus can be any suitable biocompatible means for providing a sufficient driving signal to the magnetostrictive means 4.

The device of the present invention is comprised of the magnetostrictive means 4 formed of a magnetostrictive material. A magnetostrictive material is one which is subject to the phenomenon of elastic deformation when exposed to a magnetic field. Magnetostriction is a result of the rotation of small magnetic domains which causes internal strains in the material. These strains result in a positive expansion of the magnetostrictive material in the direction of the magnetic field. As the field is increased, more domains rotate and become aligned until finally saturation is achieved, where nearly all domains are aligned in the direction of the field. If the field is reversed, the domains reverse direction but again align along the field direction and also result in an increase in the length of the magnetostrictive material.

Several materials are known to possess magnetostrictive properties. For example, nickel,

cobalt, iron and alloys of these materials have magnetostrictive effects. Terbium and dysprosium also possess significant magnetostrictive properties. A magnetostrictive means comprised of the member or body 10 formed of any material possessing magnetostrictive properties and biocompatibility with the implant recipient will suffice as the device of the present invention.

An alloy comprised of terbium, dysprosium and iron is the preferred material of the magnetostrictive member or body 10 due to the high displacement-to-energy-requirement ratio which is characteristic of this alloy. This alloy is commercially available under the trademark TERFENOL-D® from Etrema Products, Inc., a subsidiary of Edge Technologies, Inc. located in Ames, Iowa. In a specific implementation, the magnetostrictive member or body 10 is formed of a material which is represented by the chemical formula $Tb_{0.3}Fe_{2.0}Dy_{0.7}$. A manual entitled "Application Manual for the Design of ETREMA TERFENOL-D® Magnetostrictive Transducers", prepared by John L. Butler of Image Acoustics, Inc., North Marshfield, Massachusetts, is incorporated herein by reference.

To make the member 10 biocompatible, it is so adapted by a suitable biocompatible coating or casing. For example, a presently preferred embodiment includes hermetically sealing the magnetostrictive material in a titanium can which is welded shut by laser or electron beam welding. An inert precious metal coating can also be used, for example.

Referring to FIGS. 7-14, which but for the nature of the body 10 are the same as figures disclosed in U.S. Patent No. 5,015,225 (and the other two aforementioned related patents incorporated herein by reference), examples of the body 10 of magnetostrictive means 4 are shown in detail. FIG. 7 illustrates various embodiments of magnetostrictive member or body 10. FIGS. 8-14 indicate various locations in the implant auditory path

of the user in which the various embodiments of the magnetostrictive means 4 can be placed. In FIGS. 8, 12, 13 and 14 the member 10 is connected to one or more middle-ear ossicles. In FIG. 9 the proximal end of the member 10 abuts the malleus and the distal end of the member 10 abuts structure below the oval window; in FIGS. 10 and 11 the distal ends are in the oval window and the proximal ends adjoin an ossicle (the incus in FIG. 10 and the malleus in FIG. 11).

FIGS. 15-18 illustrate other, more preferred, embodiments for the disposition of the member 10. In a particularly preferred embodiment shown in FIG. 15, a "pineapple-ring" shaped device having an off-center bore defined therethrough is implanted at the incus-stapes junction. FIGS. 16 and 17 show preferred embodiments of the magnetostrictive member 10 attached to the proximal side (or alternatively, on the distal side) of the tympanic membrane medial (FIG. 16) and lateral (FIG. 17) to the handle of the adjacent malleus of the related middle-ear ossicular chain. FIG. 18 illustrates the member 10 implanted between the round window and a stabilizing bony support structure in the middle-ear.

These embodiments of magnetostrictive member or body 10, as well as their location in the implant auditory path, are illustrative only and many other embodiments are possible.

As indicated, but not limited, by the aforementioned embodiments, the size, shape and placement of magnetostrictive member or body 10 can be varied. For example, magnetostrictive member or body 10 can be considered a prosthesis replacing one or more of the small bones of the ossicular chain. Rather than replacing a portion of the ossicular chain, magnetostrictive member or body 10 can be attached to a bone of the ossicular chain. It can also be used in effect in parallel with one or more bones of the ossicular chain.

Magnetostrictive member or body 10 can also be attached to the membrane of the oval window or round window in the middle-ear, such as referred to above. The magnetostrictive member or body 10 can be positioned on the surface of the round or oval window membrane, such that magnetostrictive member or body 10 touches but does not compress the membrane (very much like the footplate of the stapes touches the oval window membrane). A similar technique can be used for the round window abutment where the magnetostrictive member or body 10 extends across the middle-ear cavity like a bridge. The magnetostrictive member or body 10 is attached at one end to the round window membrane and can be either attached at the other end to the malleus or can stand alone without attachment to the malleus. An alternate form of attachment for both the round and oval windows is to glue the magnetostrictive member or body 10 to the round or oval window membrane using fibrin glue or biocompatible cement.

To stimulate the inner ear to create the perception of sound in a human, the aforementioned apparatus is used to artificially generate sound-representing oscillations within the auditory path of the human. This includes magnetostrictively driving a member of the group consisting of ossicles of a middle-ear of the human, a membrane of the oval window adjacent the middle-ear, a membrane of the round window adjacent the middle-ear and a related tympanic membrane. The driven member produces and transmits the sound-representing oscillations into the inner ear. To do this, magnetostrictive means 4 such as a TERFENOL-D® rod, body or formed prosthesis 10 is surgically implanted, in a known manner, at a locus of the ear structure from which vibrations can be conducted, preferably by intrinsic physiological functioning, to an operative cochlea. An electromagnetic signal which corresponds to detected sound waves is then transmitted to where the magnetostrictive body 10 is located. The

magnetostrictive body 10 responds to the electromagnetic signal by elastically deforming (expanding) and restoring (contracting from the expanded state) in response to variations in the electromagnetic signal corresponding to frequencies of the sensed sound. The elastic expansion and contraction of the magnetostrictive body 10 vibrates the structure to which the body is attached (preferably, at least one of the group consisting of the small bones of the ossicular chain, the membrane of the round window, the membrane of the oval window and the tympanic membrane). Vibration of the ear structure is conveyed from the locus of the application to the cochlea in the inner ear resulting in an impulse being transmitted via the cochlea nerve to the brain, thereby creating the perception of sound in the implant recipient.

Thus, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned as well as those inherent therein. While preferred embodiments of the present invention have been illustrated for the purpose of the present disclosure, changes in the arrangement and construction of parts and the performance of steps can be made by those skilled in the art, which changes are encompassed within the scope and spirit of the present invention as defined by the appended claims.

What is claimed is:

1. A hearing aid device, comprising a body adapted to be implanted in an implant auditory path defined from a tympanic membrane through a middle-ear and oval window to a related round window of an implant recipient and composed of a biocompatibly adapted magnetostrictive material so that said body undergoes elastic deformation and restoration within the implant auditory path in response to a varying electromagnetic field applied as a representation of a sound to be perceived by the implant recipient.

2. The hearing aid device of claim 1, wherein said body is a prosthesis defined for replacing at least a portion of an ossicular chain in the middle-ear.

3. The hearing aid device of claim 1, wherein said body attaches to a bone of an ossicular chain of the middle-ear.

4. The hearing aid device of claim 1, wherein said body attaches to a membrane of the oval window.

5. The hearing aid device of claim 1, wherein said body attaches to a membrane of the round window.

6. The hearing aid device of claim 1, wherein said body attaches to the tympanic membrane.

7. The hearing aid device of claim 1, further comprising a coil for generating an electromagnetic field effecting the elastic deformation and restoration in said body.

8. The hearing aid device of claim 7, wherein said body and said coil are located within the implant auditory path.

9. The hearing aid device of claim 1, wherein said body is composed of a material comprising terbium, iron and dysprosium.

10. The hearing aid device of claim 10, wherein said material composing said body is represented by the chemical formula $Tb_{0.3}Fe_{2.0}Dy_{0.7}$.

11. An apparatus for improving the hearing of a user comprising:

sound processing means for receiving sound and for converting the sound into an electromagnetic signal; and

magnetostrictive means for vibrating within an auditory path of the user in response to the electromagnetic signal to stimulate an inner ear of the user to create the perception of sound in the user.

12. The apparatus of claim 11, wherein said magnetostrictive means includes a prosthesis for replacing at least a portion of an ossicular chain of the auditory path.

13. The apparatus of claim 11, wherein said magnetostrictive means comprises a body attached to a member of the group consisting of an ossicular chain of the auditory path, a membrane of an oval window of the auditory path and a membrane of a round window of the auditory path.

14. The apparatus of claim 11, wherein said magnetostrictive means comprises a body attached to a tympanic membrane of the auditory path.

15. The apparatus of claim 11, wherein said sound processing means is spaced from said magnetostrictive means when said apparatus is attached to the user.

16. The apparatus of claim 11, wherein at least a portion of said sound processing means is adjacent said magnetostrictive means when said apparatus is attached to the user.

17. The apparatus of claim 16, wherein said sound processing means comprises an electrical coil disposed around said magnetostrictive means.

18. The apparatus of claim 11, wherein said magnetostrictive means comprises a magnetostrictive member formed of a material comprising terbium, iron and dysprosium.

19. The apparatus of claim 18, wherein said material composing said member is represented by the chemical formula $Tb_{0.3}Fe_{2.0}Dy_{0.7}$.

20. A method of stimulating the inner ear to create the perception of sound in a human, comprising artificially generating sound-representing oscillations within an auditory path of a human, including magnetostrictively driving a member of the group consisting of ossicles of a middle-ear of the human, a membrane of an oval window adjacent the middle-ear, a membrane of a round window adjacent the middle-ear and a related tympanic membrane, in response to a sound so that the driven member produces and transmits said oscillations into the inner ear, thereby stimulating the inner ear.

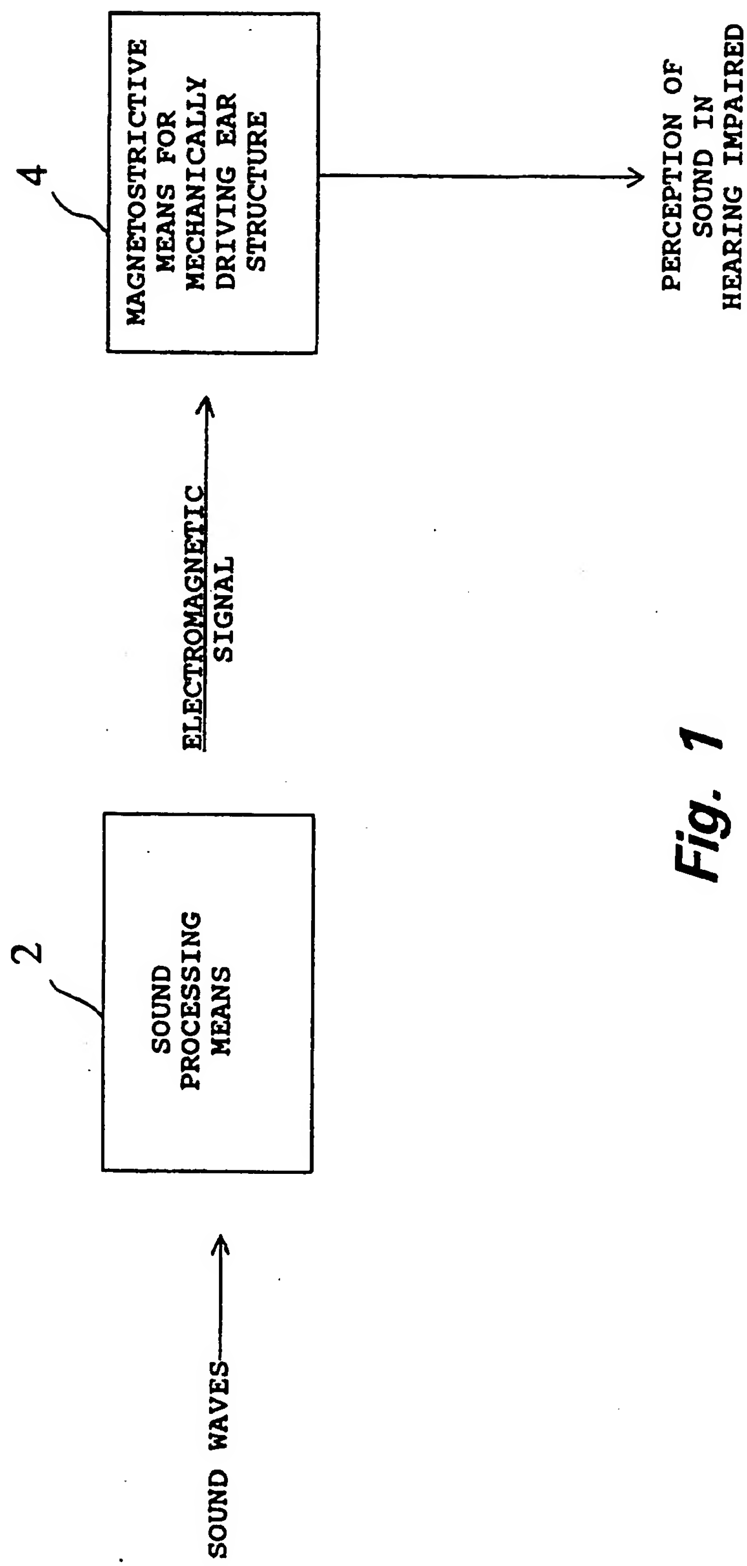

SOUND WAVES
2
SOUND PROCESSING MEANS
ELECTROMAGNETIC SIGNAL
4
MAGNETOSTRICTIVE MEANS FOR MECHANICALLY DRIVING EAR STRUCTURE
PERCEPTION OF SOUND IN HEARING IMPAIRED

Fig. 1

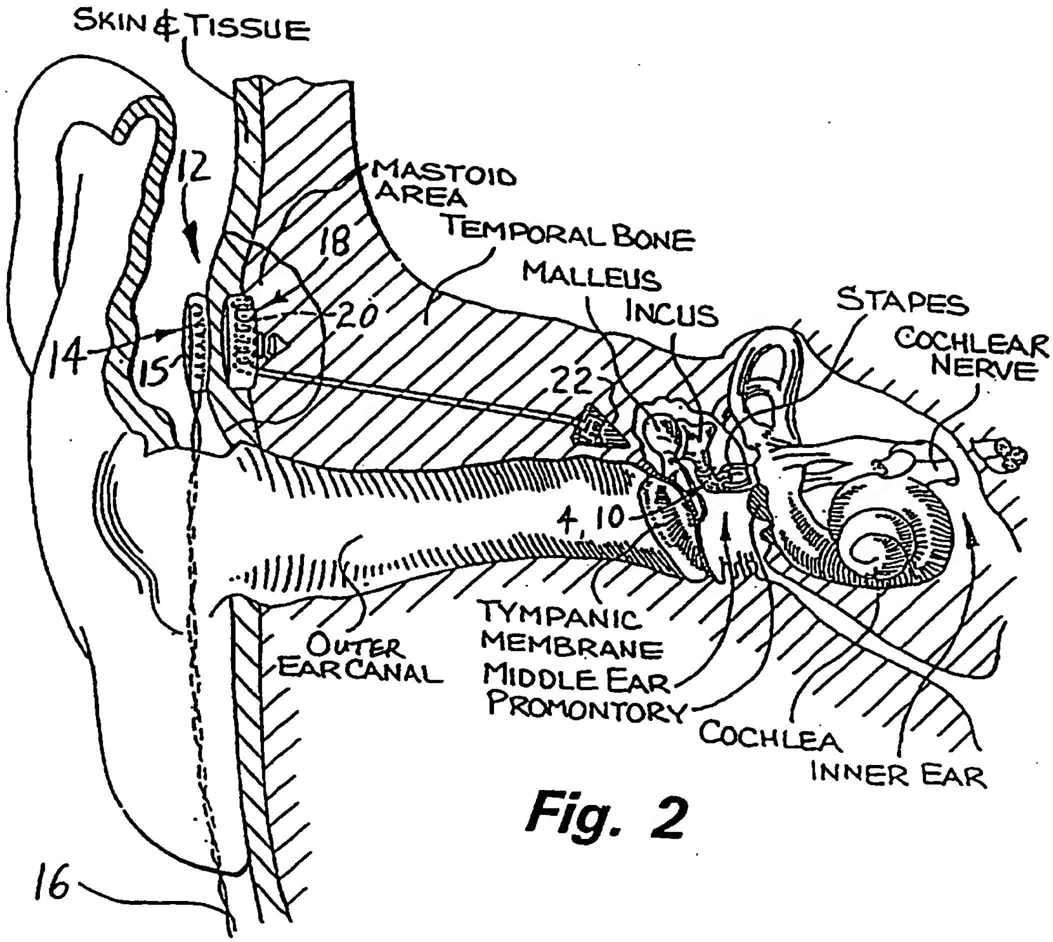
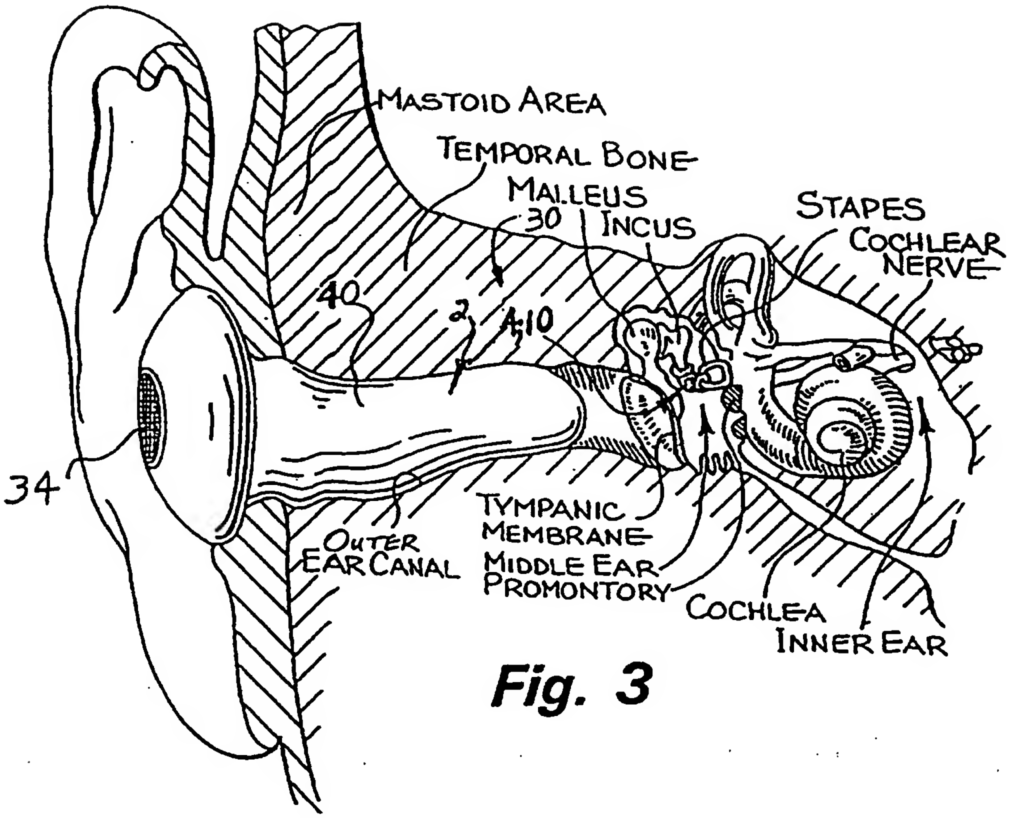
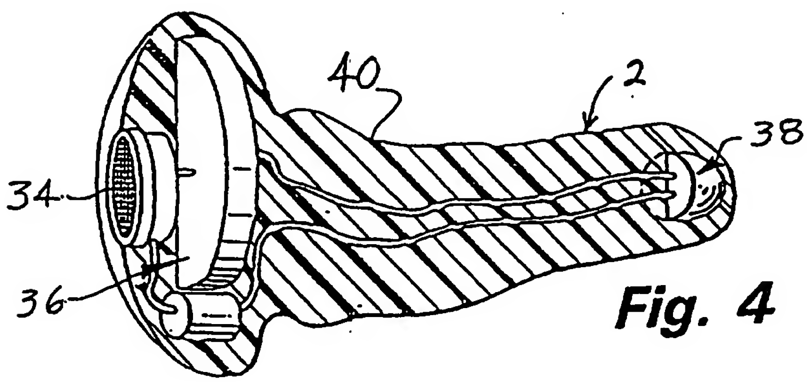

SKIN & TISSUE
12
MASTOID AREA
18
TEMPORAL BONE
MALLEUS
INCUS
STAPES
COCHLEAR NERVE
20
14
15
22
4, 10
TYMPANIC MEMBRANE
OUTER EAR CANAL
MIDDLE EAR
PROMONTORY
COCHLEA
INNER EAR
16

Fig. 2



MASTOID AREA
TEMPORAL BONE
MALLEUS
30
INCUS
STAPES
COCHLEAR NERVE
40
2
A
10
34
TYMPANIC MEMBRANE
OUTER EAR CANAL
MIDDLE EAR PROMONTORY
COCHLEA
INNER EAR

Fig. 3



40
2
38
34
36

Fig. 4

Fig. 5

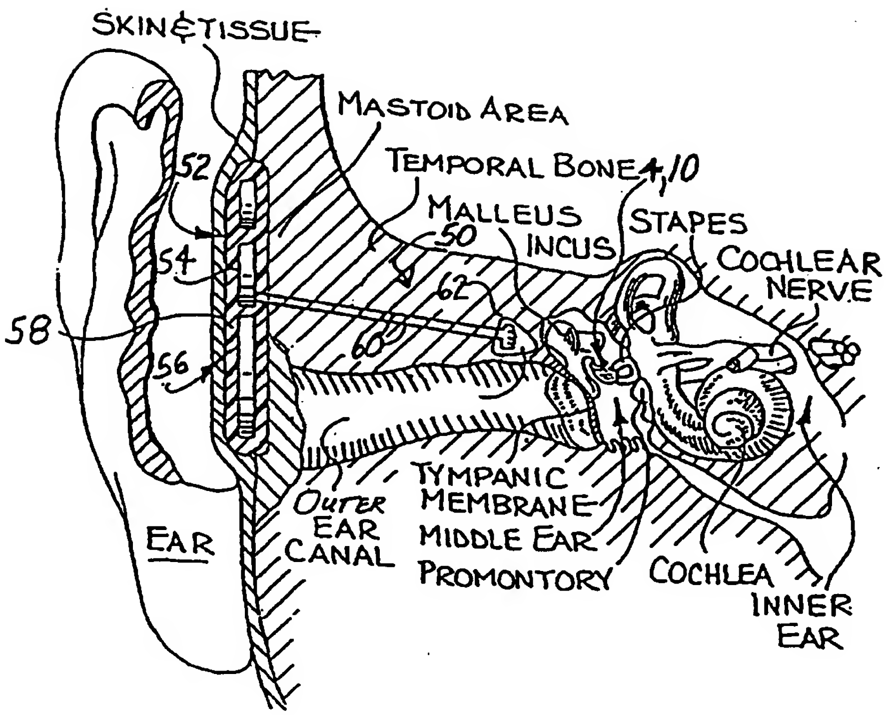
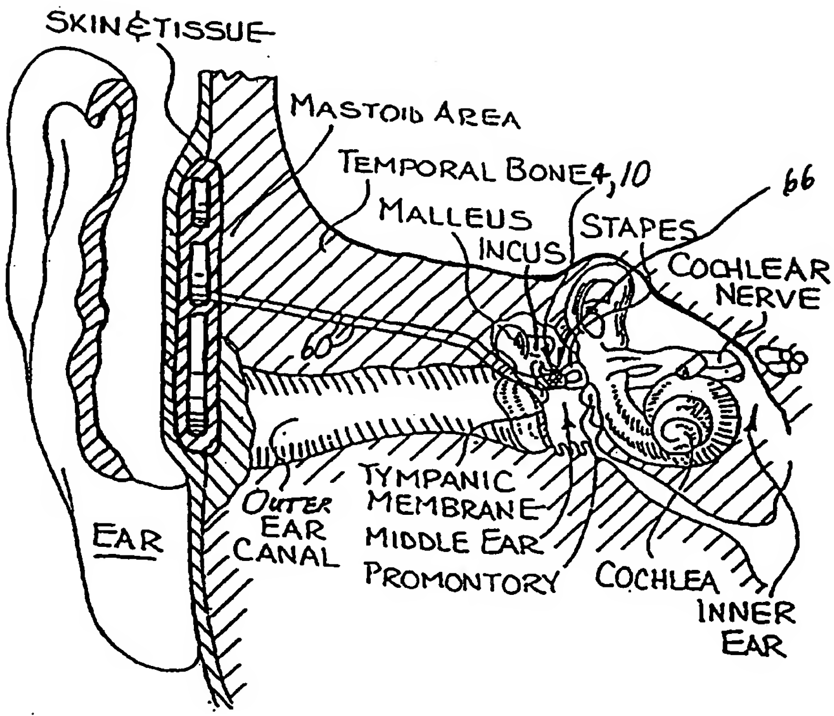

SKIN&TISSUE
MASTOID AREA
TEMPORAL BONE
4,10
52
54
56
58
50
62
60
MALLEUS
INCUS
STAPES
COCHLEAR NERVE
TYMPANIC MEMBRANE
MIDDLE EAR
PROMONTORY
COCHLEA
INNER EAR
OUTER EAR CANAL
EAR

Fig. 6


SKIN & TISSUE
MASTOID AREA
TEMPORAL BONE
4,10
66
MALLEUS
INCUS
STAPES
COCHLEAR NERVE
60
TYMPANIC MEMBRANE
OUTER EAR CANAL
EAR
MIDDLE EAR
PROMONTORY
COCHLEA
INNER EAR

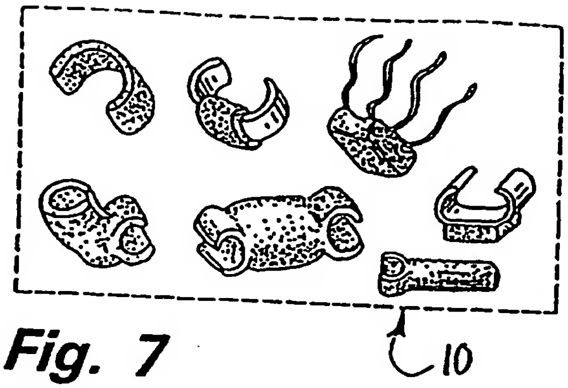


Fig. 7

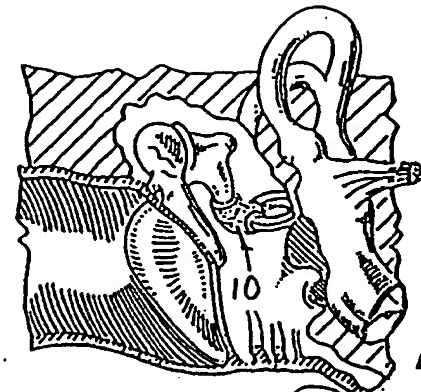


Fig. 8

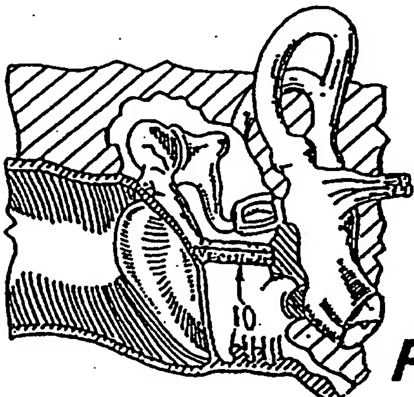


Fig. 9

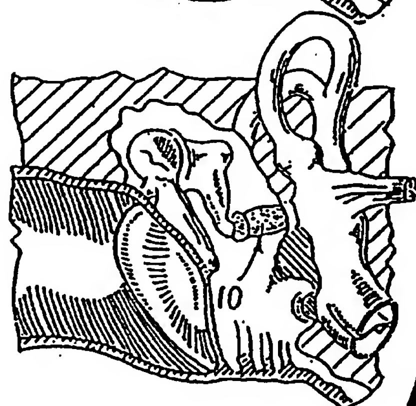


Fig. 10

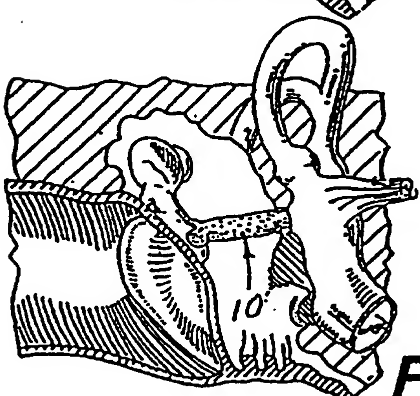


Fig. 11

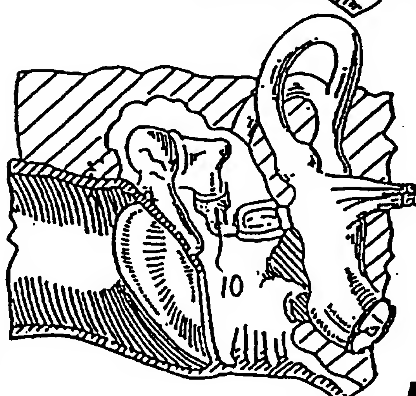


Fig. 12

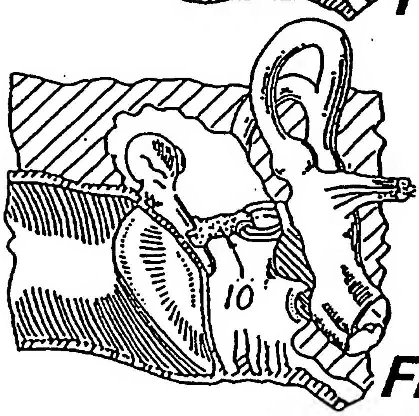


Fig. 13

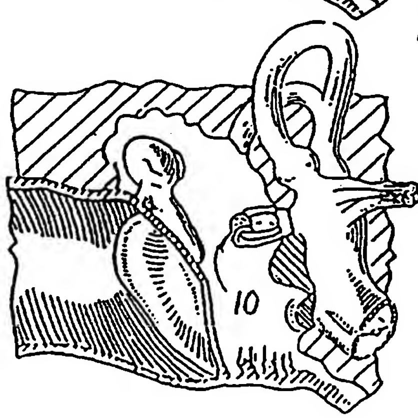


Fig. 14

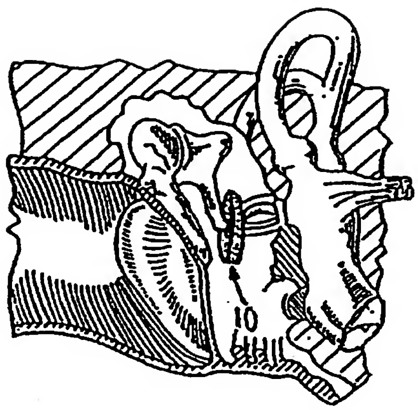


Fig. 15

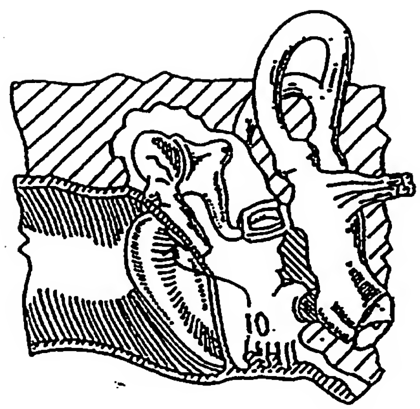


Fig. 16

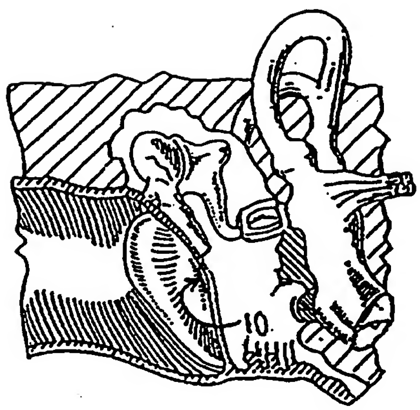


Fig. 17

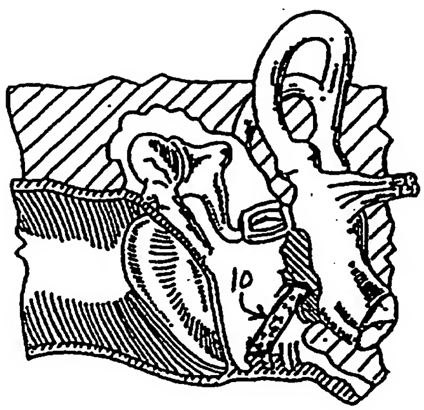


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/16994

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04R 25/00
US CL :600/025

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 181/128-137; 600/025; 606/055-057

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 4,606,329 (HOUGH) 19 August 1986, see entire document.	1-8, 11-17, 20 --- 9, 10, 18, 19
Y	ETREMA PRODUCTS, INC., NOW IMAGINE THE POSSIBILITIES, a brochure.	9, 10, 18, 19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 MARCH 1996

Date of mailing of the international search report

11 APR 1996

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Authorized officer

Andre Robinson

JOHN LACYK